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AN AMPLIFIER FOR USE WITH PIEZO-ELECTRIC GAGES TO MEASURE  
AIR BLAST PRODUCED BY SMALL EXPLOSIVE CHARGES

1 JUNE 1953



**U. S. NAVAL ORDNANCE LABORATORY**

**WHITE OAK, MARYLAND**

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AN AMPLIFIER FOR USE WITH PIEZO-ELECTRIC GAGES TO MEASURE  
AIR BLAST PRODUCED BY SMALL EXPLOSIVE CHARGES

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ABSTRACT: This amplifier is a modified version of the Y-axis amplifier in the DuMont Type 304H oscilloscope. The modification consists of incorporating an additional stage of amplification and a high impedance input circuit with a long time-constant, in addition to a highly regulated electronic power supply. The frequency response curve for sinusoidal voltages shows that this amplifier is flat from one cycle to twenty kilocycles and is down only 3 db at 135 kilocycles. The amplifier is linear over the operating range of input voltages. The sensitivity is sufficient to produce a two inch deflection on a CRO for a 3 millivolt rms input signal. This corresponds to an overall voltage gain of 82 db.

Explosives Research Department  
U.S. NAVAL ORDNANCE LABORATORY  
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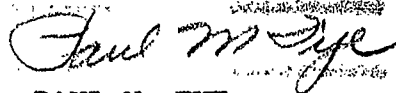
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This report was prepared under Task NOL-Re2c-67 as a description of the amplifiers used to replace the critically designed and difficult to maintain U.E.R.L. (Underwater Explosives Research Laboratory) designed type now in use at Stump Neck, Maryland. This amplifier is a modified version of the Y-axis amplifier used in the DuMont Type 304H oscillograph.

The author is especially indebted to Mr. Nicholas Maropis and Mr. E. M. Fisher for the design of the original preamplifier and for determining the capabilities of the overall amplifier.

The opinions expressed in this report are those of the author and are not necessarily the opinions of the Naval Ordnance Laboratory.

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AN AMPLIFIER FOR USE WITH PIEZO-ELECTRIC GAGES TO MEASURE  
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INTRODUCTION

1. This amplifier was developed because of the need for a relatively trouble-free amplifier to supplement or replace the critically designed U.E.R.L. (Underwater Explosives Research Laboratory) amplifiers now in use at the Naval Ordnance Laboratory. U.E.R.L. amplifiers have always been difficult to keep operating over a sustained period of time and since they have reached an age of approximately 10 years, their frequent failures and subsequent service and readjustment have become too time consuming.

2. A practical amplifier for signals from piezo-electric gages used to measure the blast produced by small explosives should have a high gain and a very high input impedance (1000 megohms used). Frequency, amplitude, and phase or time-delay distortion should be negligible. These amplifiers must be linear over the operating range of input voltages with a hum level not to exceed 0.1% of the output signal.

3. The low-level stages of the amplifiers require power supplies with very little ripple and good stability, and deviations of the output voltage from an unvarying DC voltage are sometimes required to be less than a few millivolts. It is usually necessary for the plate-supply voltage to be independent of the ordinarily encountered line-voltage fluctuations, and the drift in output voltage should be small. The internal resistance of the power supply should be sufficiently low to prevent coupling between stages of the amplifier, or between different amplifier channels. (The operation of more than one amplifier from one power supply is usually the most efficient arrangement.)

DESCRIPTION OF AMPLIFIER

4. It was decided that the simplest way to produce a suitable amplifier to fulfill the above requirements was



to modify the Y-axis DC amplifier of the DuMont Type 304H oscillograph. The frequency response of this amplifier was more than adequate, but its input impedance and sensitivity was not. In order to provide the necessary requirements as to high input impedance and higher gain a two stage preamplifier was incorporated ( $V_0$  in Fig. 1). The first stage is used as a cathode-follower to obtain high input impedance while the second stage is used as a voltage amplifier to provide an additional voltage gain of 20 db. A 12AY7 vacuum tube was selected as the pre-amplifier because of its inherently low noise factor. Figure 2 is a graph of the frequency response of the new amplifier.

a. First Stage

The input coupling to the grid of the 12AY7 is an R-C network. The capacity is 0.1 microfarad and the resistor is 1000 megohms. This provides the needed long time-constant. This cathode-follower is used primarily as an impedance transformer. It transfers the input voltage coupled across the very high grid-leak resistance from the grid to the low impedance cathode circuit with only a slight voltage loss. This transformation occurs with excellent frequency response and low distortion.

b. Second Stage

The second stage is a normal R-C coupled voltage amplifier except that it is directly coupled to the preceding cathode-follower. Bias for this triode is obtained by cathode current through the tube plus bleeder current from the plate supply as a result of a 33K resistor being connected from the cathode to  $B_+$ . The voltage gain of this stage is approximately 20 db. The plate is capacitor-coupled to the input attenuator and grid circuit of the DuMont amplifier. This 1.0 microfarad capacitor is a low leakage Tobe Type T6P1-201. Leakage voltages developed across this capacitor are impressed directly on the grid of the first triode of  $V_1$  when the attenuator switch is on the 1:1 ratio. Inability to balance the DuMont section of the amplifier is a symptom of leakage in this capacitor and it must be replaced.

c. Alternate Preamplifier

Figure 3 is a schematic of this circuit. It has been found more desirable to use this preamplifier than the original because of its simplicity, lower current drain

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and higher gain. This preamplifier differs from the one just described in that a common cathode resistor is used for both stages. Bias for both stages is obtained by the flow of plate current through this cathode resistor. Signal transfer, from the cathode-follower of the first stage to the grounded-grid amplifier of the second stage, is also accomplished by the coupling of the two stages with this common cathode impedance.

MODIFICATIONS TO 304H AMPLIFIER

5. Although the preamplifier is detrimental to the low frequency response of the amplifier, the long time-constants of the coupling circuits still allow the amplifier to be adequate for transient air blast pressures. The overall time-constant of the amplifier is 2 seconds. This indicates a step-function will decay to  $\frac{1}{e}$  of its initial value in this period of time.

6. Another modification to the DuMont amplifier is a change in the attenuator circuit. Section S1-A of the selector switch was removed and the 1000:1 attenuator and its associated circuitry was deleted.

7. Complete details concerning the remaining stages of this amplifier are available in the DuMont Type 304H oscillograph instruction book (reference (a)).

8. The plate power supply for the 304H amplifier is not adequate for the modified version because of the high hum content. The increased level of hum in the modified amplifier output is due to the higher sensitivity of the amplifier and the use of single-ended stages in the preamplifier. Another point that is susceptible to electrostatic and magnetic fields is the high impedance grid-circuit of the cathode-follower. Shielded wiring and careful positioning of the components in the grid-circuit, will minimize hum pickup at this point. Before the doubly regulated supply (described below) was used, considerable interaction occurred between the two amplifiers of a unit using a single power supply. However this has been remedied considerably with the doubly regulated power supply, so that now only a very slight amount of observable interaction occurs. This interaction takes place after the pressure-time record has been recorded.

9. To reduce the power-frequency voltage components in the amplifier plate-power source, a doubly regulated power supply was incorporated. This power supply is a modified

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U.E.R.L. unit (reference (b)), which supplies the 105 volt and the 395 volt sources at the required current levels. Each amplifier has a current drain of 20 milli-amperes. Three changes were made in the U.E.R.L. power supply. The first was the replacement of the two 6A3 vacuum tubes with a 6AS7. A 6AQ5 was substituted for a 6V6 and all critical resistors were changed to high wattage wire-wound resistors. These changes were made to conserve space and to increase the stability of the power supply. Figure 4 is a schematic of the power supply.

10. Two modified 304H amplifiers and a power supply make up a complete unit. A top view showing the relative position of the amplifier and power supply, and a bottom view showing the under chassis components and wiring of the power supply is shown in Fig. 5. A front view of a complete unit, two amplifiers and one power supply is shown in Fig. 6. The construction and wiring of an amplifier is shown in Fig. 7.

11. Three complete units have been in use at the NOL blast field at Stump Neck, Maryland with very little needed maintenance. The performance of these amplifiers has been quite satisfactory during this period. However, it has been observed that the output voltage is still affected by line voltage fluctuations. Care should be taken to insure that the input voltage exceeds 105 volts.

12. The White Oak Air Blast Group has adopted the DuMont Type 304H amplifiers with the addition of the alternate preamplifier described earlier in this report. However, these are the Y-axis amplifiers still in their original oscillograph housing. The preamplifiers for eight channels are plug-in units on a 3-inch rack panel. The regulated power supply, described earlier, is used to provide the necessary filament and plate voltages for eight preamplifiers.

13. The following table compares the new amplifier with the old U.E.R.L. amplifier:

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	<u>New Amplifier</u>	<u>U.E.R.L. Amplifier</u>
a. Sensitivity (gain)	12,000 - 82 db	60,000 - 96 db
b. Frequency Response	1-135,000 cycles	1-100,000 cycles
c. Linearity	Good	Good
d. Time-constant	2 sec	1.1 sec
e. Serviceability	Very Good	Poor
f. Comparative space occupied (unit)	1/3	1
g. Stability	Good	Good



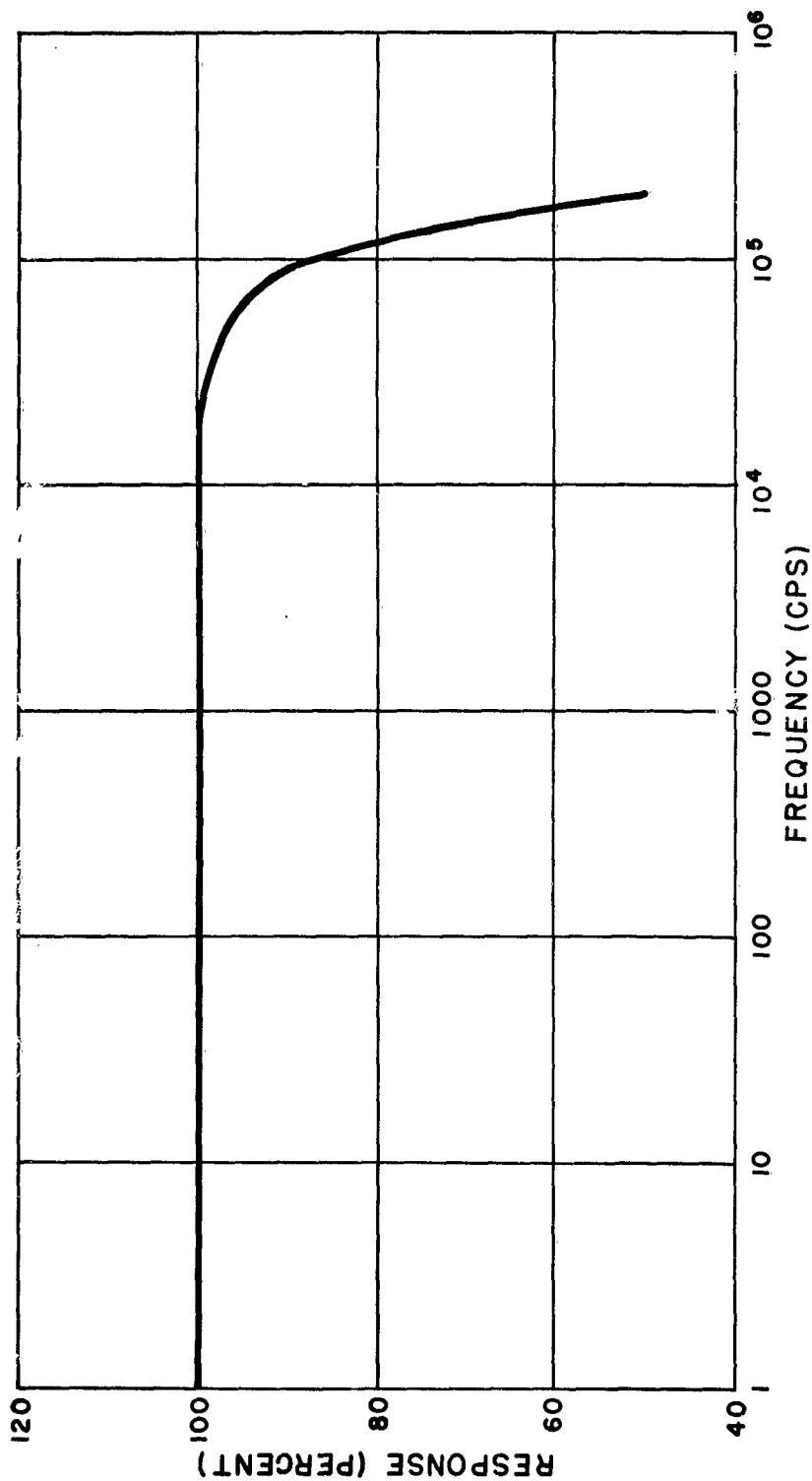


FIG. 2 FREQUENCY RESPONSE CURVE OF AMPLIFIER

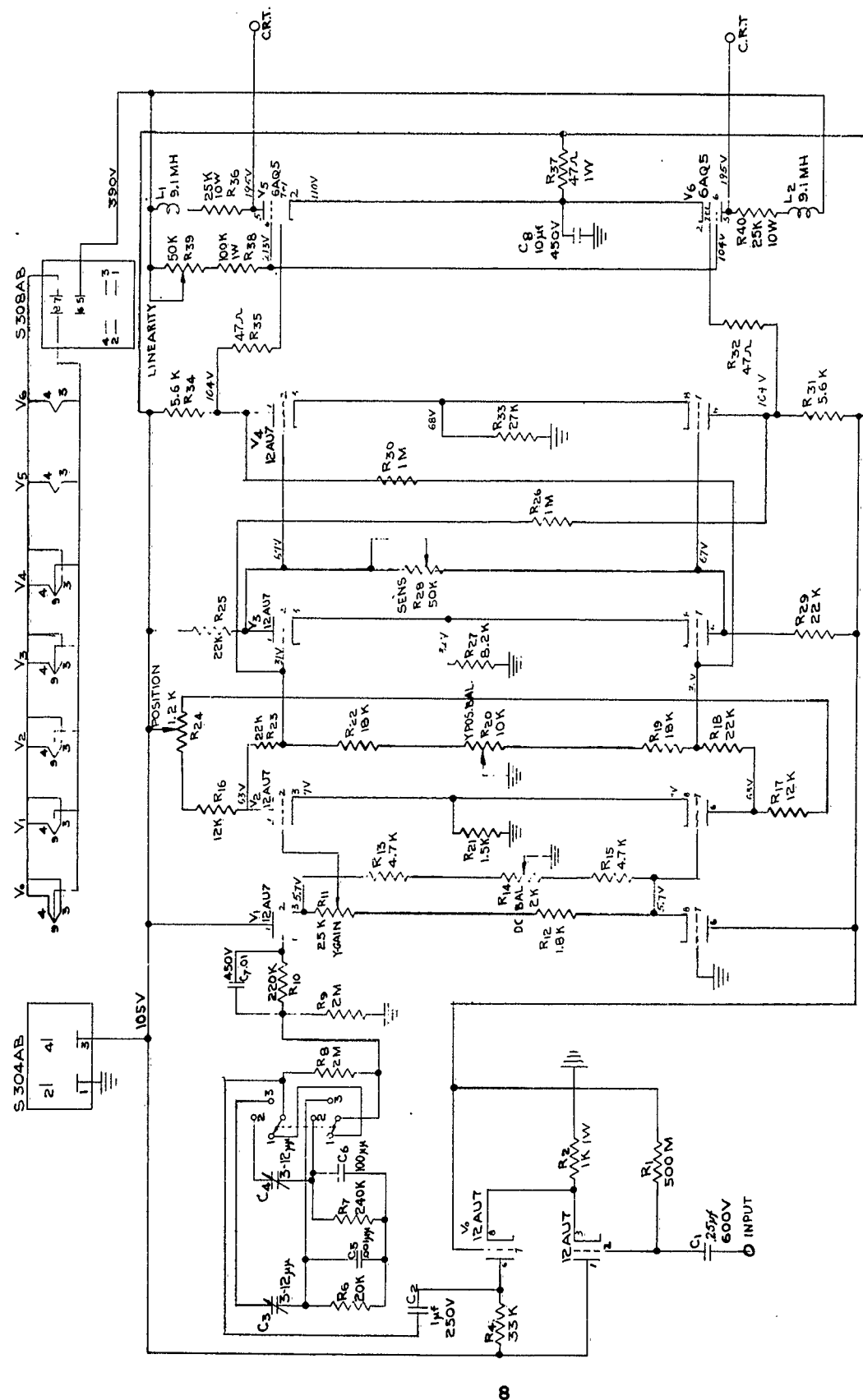


FIG. 3 STUMP NECK AMPLIFIER (ALTERNATE)

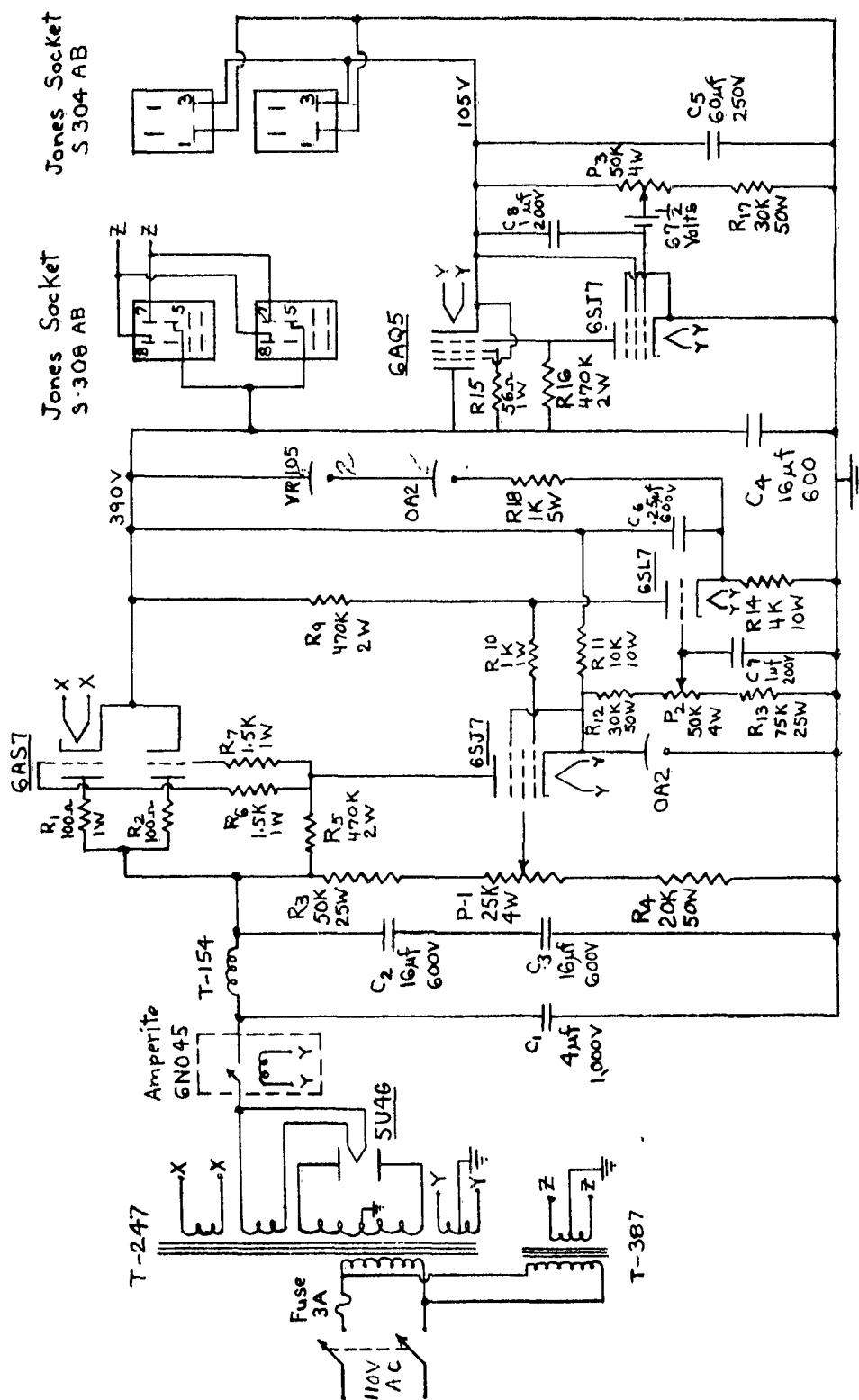
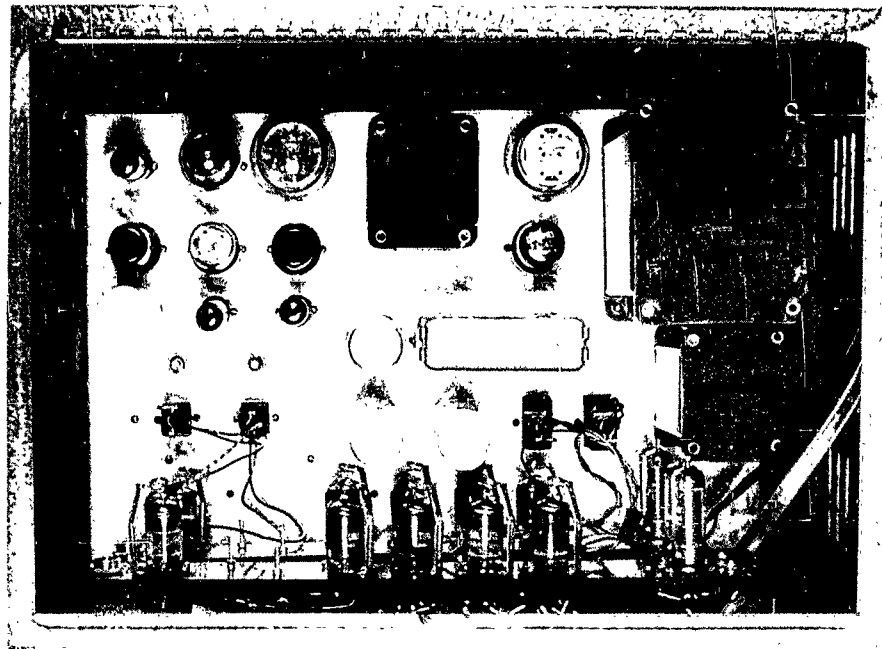
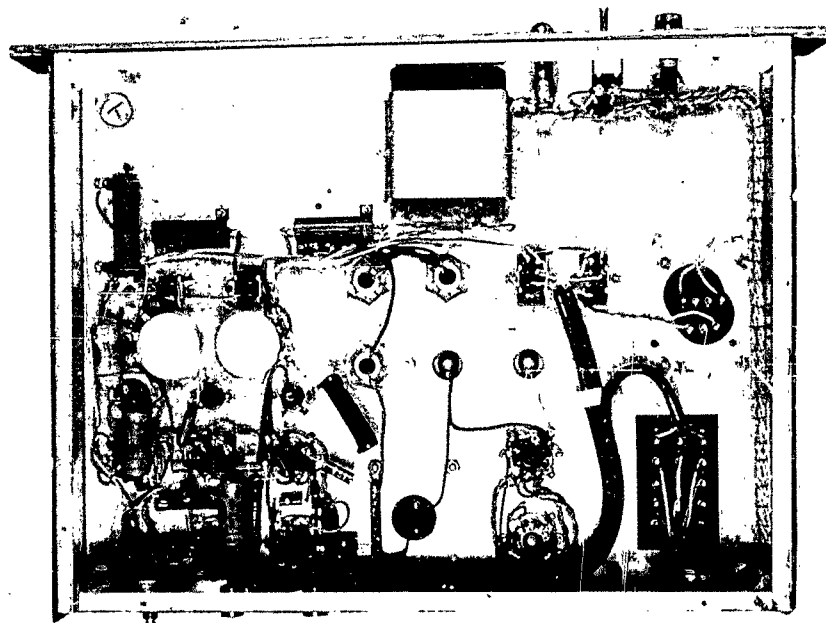


FIG. 4 POWER SUPPLY STUMP NECK AMPLIFIER





TOP VIEW OF UNIT



BOTTOM VIEW OF UNIT

FIG. 5



FIG. 6 PANEL VIEW OF A COMPLETE UNIT

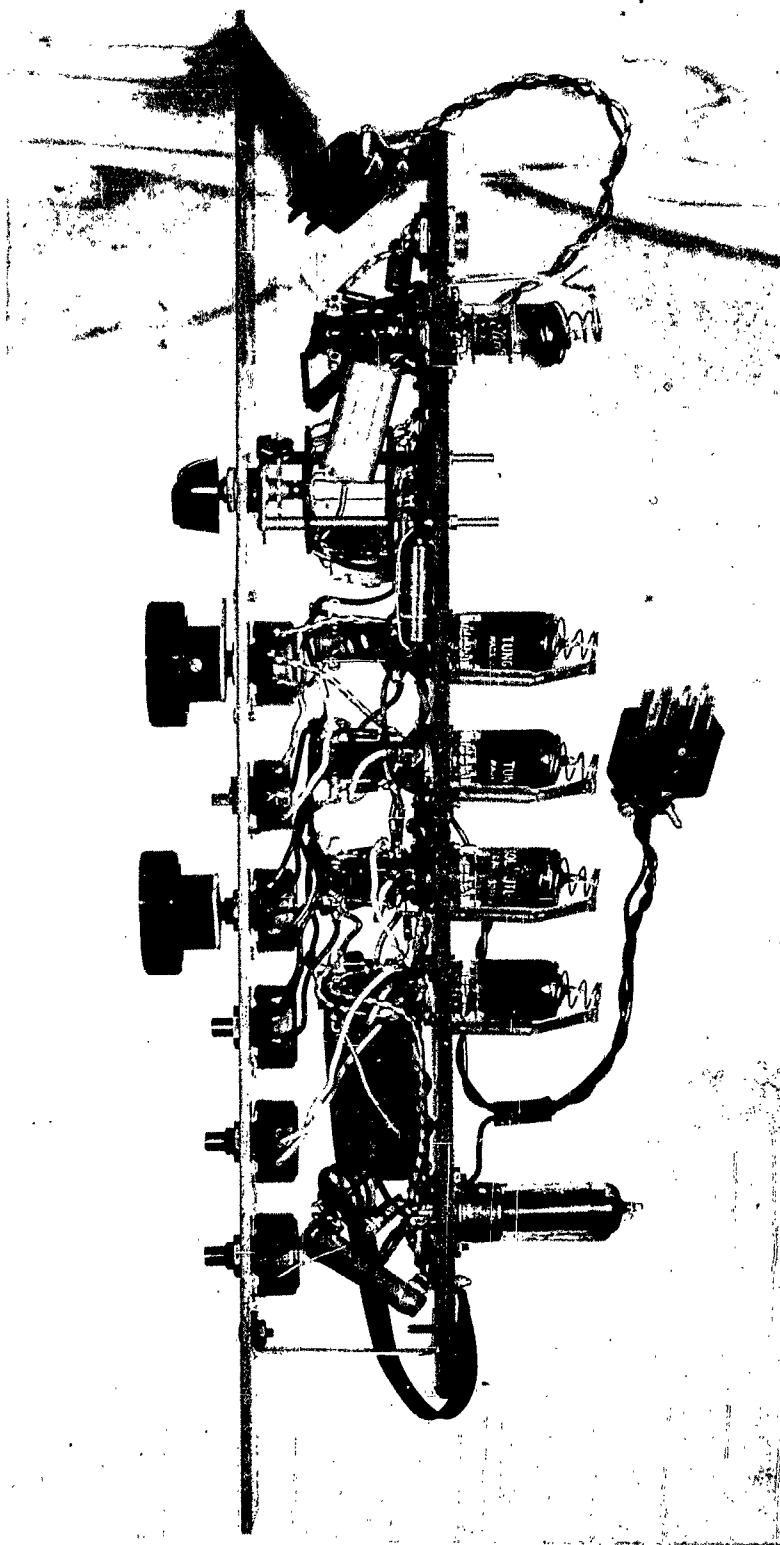


FIG. 7 AMPLIFIER SUB CHASSIS

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- (a) Allen B. DuMont, Operating and Maintenance Manual for the DuMont Type 304H Cathode Ray Oscilloscope (1951).
- (b) G. K. Fraenkel, Apparatus for the Measurement of Air Blast Pressures by Means of Piezo-Electric Gages, 1946, OSRD 6250.
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- (d) MIT Radiation Laboratory Series. Vacuum Tube Amplifiers, Vol. 18.
- (e) Gilbert Swift, Amplifier Testing by means of Square Waves, Communications, February 1939.

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